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Profit taxation and capital accumulation in a dynamic oligopoly model☆

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ABSTRACT

We illustrate a differential oligopoly game using the capital accumulation dynamics *à la* Ramsey. We evaluate the effects of profit taxation, proving that there exists a tax rate yielding the same steady state social welfare as under social planning. Contrary to the static approach, our dynamic analysis shows that, in general, profit taxation affects firms' decisions concerning capital accumulation and sales. In particular, it has pro-competitive effects provided that the extent of delegation is large enough (and conversely).

1. Introduction

There exists a relatively large literature on profit taxation in static models of imperfect competition (Levin, 1985; Besley, 1989; Delipalla and Keen, 1992; Dung, 1993; Denicolò and Matteuzzi, 2000; Ushio, 2000, *inter alia*). A well established result of this literature is that the taxation of operative profits (defined as the profits gross of fixed costs) is neutral, in that it does not affect first order conditions on market variables.

The dynamic interaction between capital accumulation and taxation has been analysed by Hall and Jorgenson (1967).[2] However, their analysis, as well as the debate stemming from what is now conventionally labelled as Jorgenson's model, is carried out focussing upon monopoly.[3]

In the light of the above mentioned streams of literature, one would like to characterise the influence of taxation on the behaviour of firms in a dynamic setting where strategic interaction is duly accounted for. To this aim, we propose a dynamic capital accumulation game in a Cournot oligopoly *à la* Ramsey (1928), i.e., a "corn–corn" growth model, where accumulation is based upon unsold output and coincides with consumption postponement. In both settings, our aim consists in characterising the effects of profit taxation on the steady state behaviour of firms and the associated performance of profits and social welfare. In order to account for the (more realistic) possibility for firms not to be strict profit-seeking agents, we assume, throughout our analysis, that firms may delegate control over their strategic decisions to managers who are interested in expanding sales *à la* Vickers (1985; see also Fershtman and Judd, 1987). This, to the best of our knowledge, is a new perspective on the effects of taxation in the Ramsey model, which so far has been extensively analysed under the classical assumption of a representative consumer/producer embedded in a perfectly competitive environment, as in Xie (1997); Karp and Lee (2003) and Cellini and Lambertini (2007a), *inter alia*. In these contributions, and in many related ones, the discussion focusses upon the time consistency of optimal taxation and the possibility of delegating the design of such a policy to a benevolent planner as a remedy to the myopic behaviour of the (atomistic) representative

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[2] For an exhaustive overview on the effects of uncertainty on investment decisions, with and without taxation, see Dixit and Pindyck (1994).

[3] For the analysis of optimal taxation of polluting emissions in a monopoly model, see Benchekroun and Van Long (2002).

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agent. Here, we explicitly assume the market be characterised by a non-negligible degree of market power, so that crucial production decisions are taken by oligopolistic firms interacting strategically.

We focus on the open-loop solution of the dynamic game. Our main results are as follows. First, profit taxation distorts capital accumulation and the associated market performance of firms in steady state, as long as firms are managerial. The distortion disappears if all firms are strictly entrepreneurial units, i.e., pure profit-seekers. This sharply contrasts with the conventional wisdom generated by the static approach to taxation in oligopoly; such a difference comes from the fact that, if one takes the more realistic view that capacity accumulation is a dynamic process, then one can verify that indeed the presence of a tax rate on profits enters firms' optimality conditions in a non-neutral way, contrary to what happens in a static model where taxation has only a scale effect on profits. Second, we prove that, even if all firms were pure profit-seeking units, then taxation would affect the optimal sales decision at any time during the game, except in steady state. This is tantamount to saying that, while the neutrality result drawn from the static analysis indeed portrays the long run outcome of a dynamic model, it cannot grasp the *ad interim* distortionary bearings of taxation on firms' decision (and therefore also on market price and consumer surplus). It is worth emphasising that this is not just a qualitative *nuance* of the model, but a substantive feature of it, to the extent that the game may last for long (in fact, in our approach, forever), with the distortionary effects of taxation disappearing only on doomsday. These properties are replicable under the feedback information structure, although the feedback solution cannot be fully outlined analytically. However, based on the concavity of the value function, there clearly emerges that the more intense strategic interaction generated by feedback information makes the feedback equilibrium output more sensitive to the presence of profit taxation, as compared to the market-driven solution of the open-loop game.

We also characterise the optimal tax rate, from the standpoint of a policy maker aiming at the maximization of social welfare in steady state. We show that there exists a tax rate driving the price to marginal cost in steady state, and that such a tax rate is monotonically increasing in the size of the market and monotonically decreasing in the number of firms.

The remainder of the paper is structured as follows. The setting is laid out in Section 2. Section 3 contains the equilibrium analysis and examines the effects of taxation at the steady state equilibrium. The feedback game is briefly dealt with in Section 4. Section 5 contains concluding remarks.

2. The basic setup

The market exists over $t \in [0, \infty)$, and is served by N firms producing a homogeneous good. Let $q_i(t) \geq 0$ define the quantity sold by firm i at time t. The marginal production cost is constant and equal to c for all firms. Firms compete *à la* Cournot, the demand function at time t being:

$$p(t) = A - BQ(t),\ Q(t) \equiv \sum_{i=1}^{N} q_i(t). \tag{1}$$

In order to produce, firms must accumulate capacity or physical capital $k_i(t)$ over time, according to the following dynamic equation (Ramsey, 1928):

$$\frac{dk_i(t)}{dt} \equiv \dot{k}_i = f(k_i(t)) - q_i(t) - \delta k_i(t), \tag{2}$$

where $f(k_i(t)) = y_i(t)$ denotes the output produced by firm i at time t. As in setting [A], we assume $f' \equiv \partial f(k_i(t))/\partial k_i(t) > 0$ and $f'' \equiv \partial^2 f(k_i(t))/\partial k_i(t)^2 < 0$. In this case, capital accumulates whenever $y_i(t) - q_i(t) > 0$, and conversely. This can be interpreted in two ways. The first consists in viewing this setup as a corn–corn model, where unsold output is reintroduced in the production process. The second consists in thinking of a two-sector economy where there exists an industry producing the capital input which can be traded against the final good at a price equal to one (for further discussion, see Cellini and Lambertini, 1998, 2007b).[4] The control variable is $q_i(t)$, while the state variable is $k_i(t)$. In the remainder of the paper, we will consider an oligopoly where the control of firms' behaviour is delegated to managers characterised by a preference for output expansion. As in Fershtman (1985), Vickers (1985)Fershtman and Judd (1987), Lambertini (2000) and many others,[5] we assume that delegation contracts are observable and establish that the manager of firm i maximises a combination of profits and output, so that his instantaneous objective function is:

$$M_i(t) = \pi_i(t) + \theta_i q_i(t) \tag{3}$$

where parameter θ_i measures the extent of delegation. If $\theta_i = 0$, the firm is entrepreneurial, i.e., it is run by stockholders so as to strictly maximise profits. Moreover, we assume that firms' profits (gross of investment costs) are taxed at a constant rate τ.

Firm i's objective is to maximise the discounted payoff flow

$$J_i(t) = \int_0^{\infty} M_i(t) e^{-\rho t} dt$$

where $\rho \geq 0$ is a constant discount rate common to all firms, s.t. the set of dynamic constraints (2) and the vector of initial conditions concerning the state variables, which we assume to be symmetric across firms for the sake of simplicity, $k_i(0) = k_{i0}$ for all $i = 1, 2, 3, \ldots, N$.

3. Equilibrium analysis

Given that, in view of the functional form of technology, the problem at hand is not defined in linear-quadratic form, we will focus on the open-loop solution.[6] Under the dynamic constraint (2), the Hamiltonian of firm i is:

$$\begin{aligned}\mathcal{H}_i(t) = {} & e^{-\rho t}[A - Bq_i(t) - BQ_{-i}(t) - c](1-\tau)q_i(t) + \theta_i q_i(t) \\ & + \lambda_{ii}(t)[f(k_i(t)) - q_i(t) - \delta k_i(t)] + \sum_{j \neq i} \lambda_{ij}(t)[f(k_j(t)) \\ & - q_j(t) - \delta k_j(t)],\end{aligned} \tag{4}$$

where τ is the constant tax rate, $Q_{-i}(t) = \sum_{j \neq i} q_j(t)$ is the amount of sales of all firms other than i at any time t and $\lambda_{ij}(t) = \mu_{ij}(t) e^{\rho t}$ is the co-state variable (evaluated at time t) that firm i associates with the state variable $k_j(t)$.

The first order condition (FOC) concerning the control variable is:

$$\frac{\partial \mathcal{H}_i(t)}{\partial q_i(t)} = [A - 2Bq_i(t) - BQ_{-i}(t) - c](1-\tau) + \theta_i - \lambda_{ii}(t) = 0. \tag{5}$$

Inspecting the above FOC immediately reveals that, at a generic instant t during the game, profit taxation is non-neutral unless θ_i and $\lambda_{ii}(t)$ are both simultaneously equal to zero. Now note that, while it is admissible that $\theta_i = 0$ (i.e., the firm has not hired a manager or, if it has, the delegation contract imposes strict profit maximisation forever), the condition $\lambda_{ii}(t) = 0$ at all t's would clearly imply that the shadow value of an additional unit of capital

[4] See also Calzolari and Lambertini (2006, 2007), where the same dynamic structure is used to investigate the viability of tariffs, quotas and export restraints in an open economy with capital accumulation and intraindustry trade.

[5] For a recent overview of this literature, see Jansen et al. (2007).

[6] Note, however, that if the capital endowment of every firm at time zero is sufficiently large, then the open-loop solution is indeed strongly time consistent and therefore subgame perfect. The proof is in Cellini and Lambertini (2008).